Multi-Attribute Decision Making (MADM) in Analysis of a Future Sensor Capability

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Background

- MSBL supports EN, MP, CM Schools and the Maneuver Support and Protection Warfighting Function (WfF).
- MSBL manages a virtual Base Defense Operation Center (BDOC).
- Through One Semi-Automated Forces (OneSAF) and additional sensor software, the BDOC can simulate capabilities of future Army systems under development.

Testing a Future Capability

- A future sensor capability would allow for the sharing of information between sensors and systems in a dynamic tactical environment.

- The BDOC represented a virtual base camp, which allowed for testing of the representative future capabilities.

- Problem: How does this future sensor capability impact the BDOC Commander’s mission effectiveness?

Experiment Overview

- Participants: Six Active Duty Soldiers (3 SSG, 1 SFC, 2 CPT) served as BDOC commanders for the two week experiment.

- Baseline (current sensor arrangement / no additional capabilities) vs. enhanced/ future capability.

- The baseline scenario made operator wait approximately ten minutes to regain sensor feed. The enhanced capability run allowed for immediate sensor availability.

Available Experiment Sensors

Rapid Aerostat Initial Deployment (RAID)

Boomerang Gunshot Detector

Pelco Camera

Long Range Thermal Imaging (LRTI)

Initially <u>on</u> and available at the beginning

Cerberus

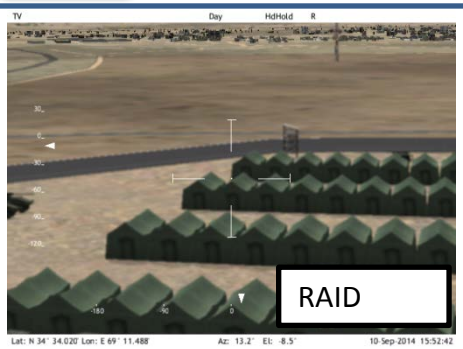
Patrol video camera

Unmanned Aerial System (UAS)

Initially <u>off</u> but available during the scenario

All images found from online search.

OneSAF Images



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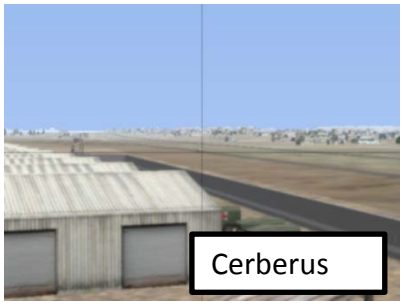
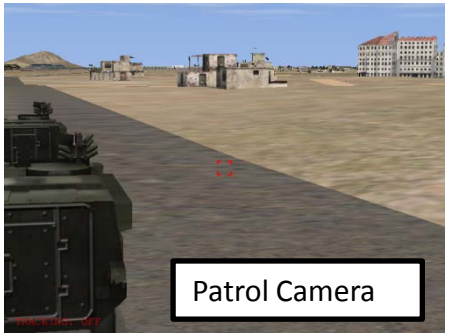
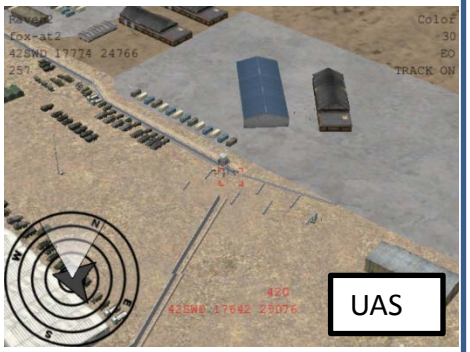






Initially <u>off</u> but available during the scenario

BDOC Set up

Unmanned Aerial System (UAS) operator

OneSAF control station

Data collector

Radio operator

Experiment Overview

- Three scenarios (25 minutes each):
  1. Three vehicle patrol is patrolling outside of the base camp. At five minute mark, RAID sensor feed is removed. At ten minute mark, enemy sniper engages patrol.
  2. No enemy action, but BDOC loses all video feed.
  3. Civilian protest at front gate. At five minute mark, RAID sensor feed is removed. At ten minute mark, Vehicle Borne Improvised Explosive Device (VBIED) explodes outside of base camp.
- Data recorder: recorded time to detect, identify, decide, SALT report, radio time, survey afterwards.

Constraints, Limitations, Assumptions

- Constraints:
  - The virtual BDOC environment tested the participants' use of this future capability. No real world testing of actual capabilities was available.
- Limitations:
  - The limited experiment preparation time did not allow for a full spectrum of stakeholder or Warfighter input.
- Assumptions:
  - The simulation served as a realistic replication of a small (50-299 Soldiers) base camp.
  - All of the participants' input is equally weighted.
  - All collected will be used for the experiment; no outliers will be discarded.

Multi-Attribute Decision Making (MADM)

Four common characteristics:

1. There are multiple objectives and attributes.
2. Objectives & attributes conflict with each other to some extent and tradeoffs apply (i.e., increasing the level of achievement for one objective or attribute may result in a decrease in the level of achievement for one or more of the remaining objectives and attribute).
3. Units of measurement are not the same across all attributes.
4. Purpose of analysis is to evaluate all alternatives and/or select best alternative.

Multi-Attribute Decision Making (MADM)

1. Identify stakeholders.
   - Customer, MSCoE Leadership, Subject Matter Experts
2. Identify fundamental objectives.
   - Determine impact of future capability to BDOC Commander's threat response.
3. Develop the qualitative model.
   - Understand what attributes are important to the stakeholder.
4. Develop quantitative value model.
   - Leads to Data Collection Management Plan (DCMP).
   - Develop and Assess value functions for each attribute.

Customer Experiment Goals

Measure	Reqt Trace	Factor	Baseline Value	Previous Quarter Value	Current Value	Target Value	Meas.	Current TRL
Increase ability to identify shooters, return fire, and reduce time to respond (10 – 30s)	X	Inter	Inability to Identify Shooters	Inability to Identify Shooters in <30s	Inability to Identify Shooters in <30s	Able to Identify Shooters in <30s	Possible use of VBDOC? Establish Sim to evaluate this	3
	X	Inter		Able to Return Fire in <X seconds	Able to Return Fire in <X seconds	Able to Return Fire in <30 seconds	VBDOC?	3
	X	Inter		Able to respond in < Y seconds	Able to respond in < Y seconds	Able to respond in <30 seconds	VBDOC?	3
Hold off attackers at a small base for 30 minutes	X	Inter		System specific	System specific	Hold off attackers at a small base for 30 minutes	VBDOC?	4
Reduce bandwidth requirements within a tactical environment	X	Inte		m specific	System specific	Reduce bandwidth requirements within a tactical environment by 30%	VBDOC Sim. E14 evaluation ?	3
Enable communication across bandwidth limited	X	Inter	No	No	Yes, Interoperability at Tactical Service Level (TSL) 1 is being worked in the current	Yes, at Interoperability	VBDOC Sim. E14 evaluation	3

Time required to Detect, Identify, Decide.

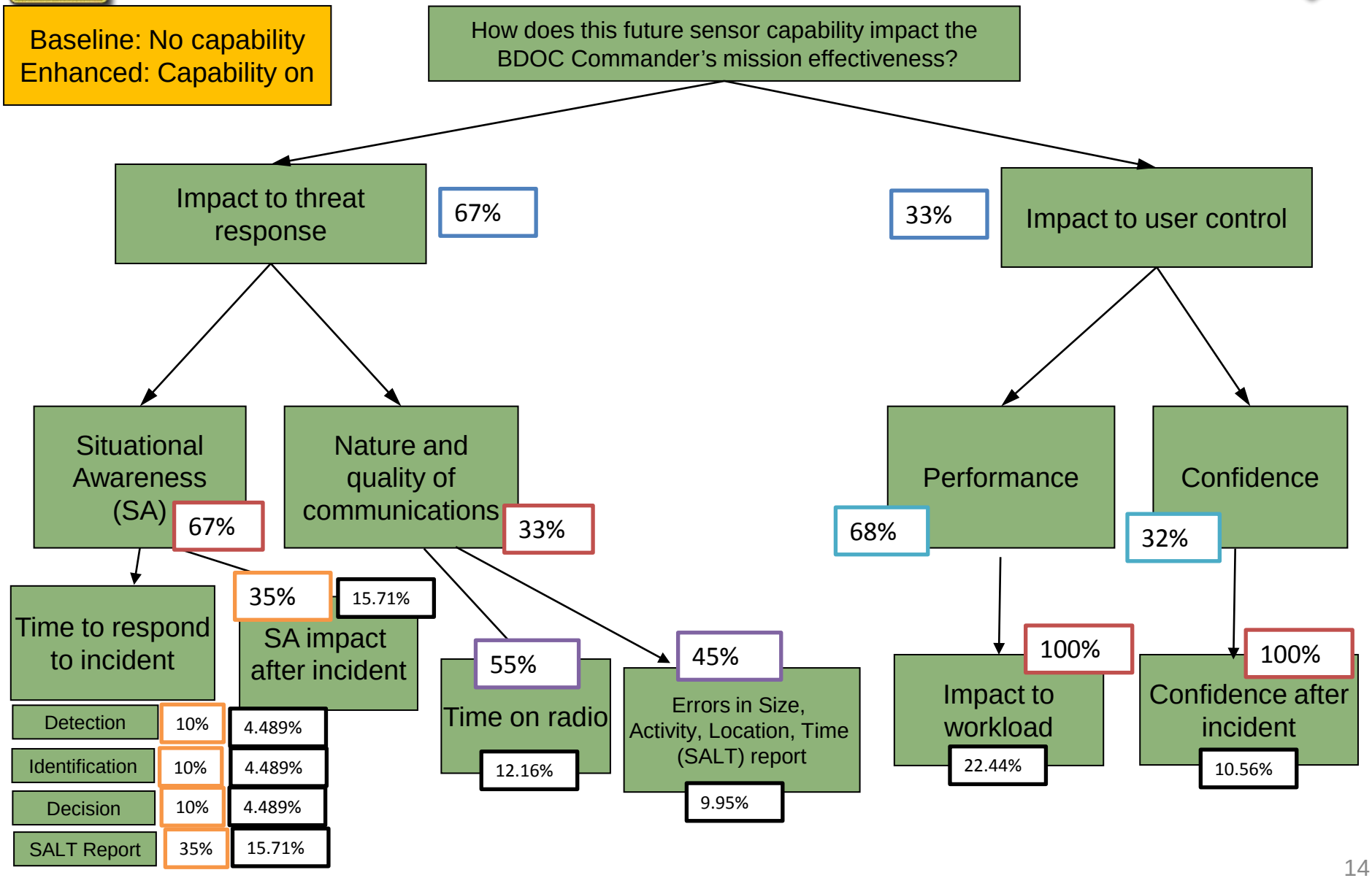
Communication

Additional Desired Measure

Situational Awareness after sensor is removed.

Qualitative Model

Baseline: No capability
Enhanced: Capability on

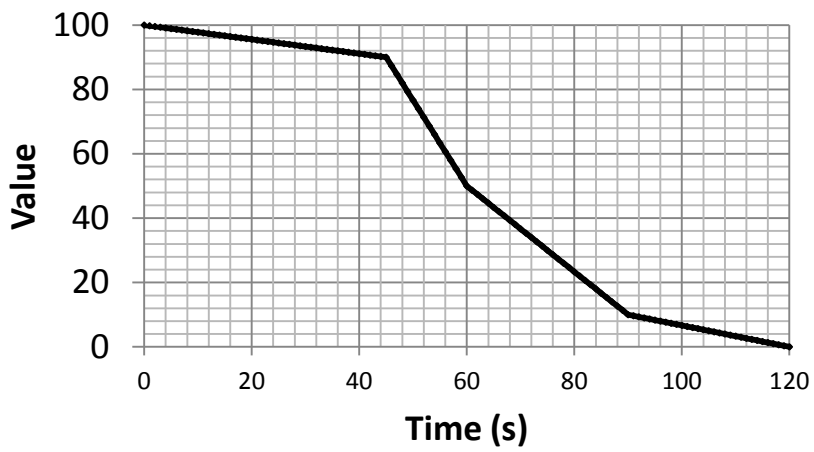


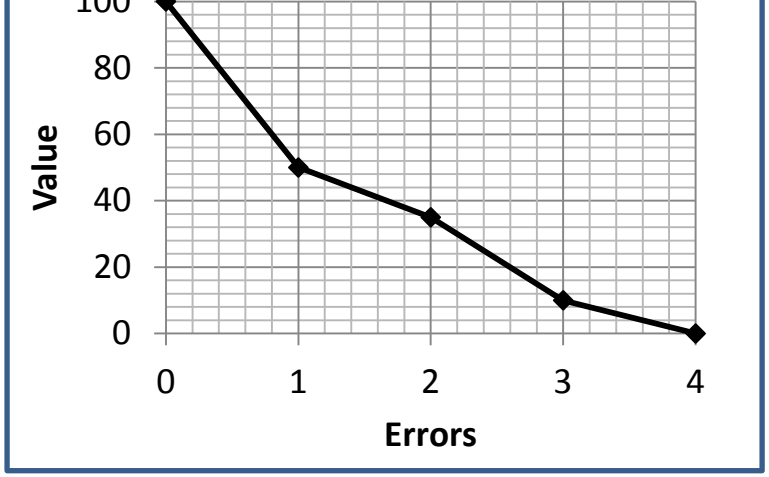
Quantitative Model / Data Collection Plan

Issue and (weighting)	Essential Elements of Analysis (EEA) and weighting	Measure of Performance (MOP) and weighting	Method and (Units)
Issue 1. (67%): How does the future sensor capability impact threat response?	EEA 1.1 (67%): How does the future sensor capability impact situational awareness (SA)?	MOP 1.1.1 (10%): What is the time from incident to detection?	Timer (seconds)
		MOP 1.1.2 (10%): What is the time from detection to identification?	Timer (seconds)
		MOP 1.1.3 (10%): What is the time from identification to decision?	Timer (seconds)
		MOP 1.1.4 (35%): What is the time from incident to complete a Size, Activity, Location, Time (SALT) report?	Timer (seconds)
		MOP 1.1.5 (35%): After a sensor failure, how was your ability to regain situational awareness impacted?	Survey (Normalized 0-100 Scale)
	EEA 1.2 (33%): How does the future sensor capability impact quantity and nature of communications?	MOP 1.2.1 (55%): What is percent of radio communication time?	Timer (percent)
		MOP 1.2.2 (45%): How many errors are in the SALT report?	Data Recorder (observation)
Issue 2. (33%): How does the future sensor capability impact user control?	EEA 2.1 (68%): How does the sensor data feed impact user performance?	MOP 2.1.2 (100%): What is the workload impact?	Survey (Normalized 0-100 Scale)
	EEA 2.2 (32%): What are the impacts on user confidence?	MOP 2.2.1 (100%): How does the future sensor capability impact user confidence in responding to a threat?	Survey (Normalized 0-100 Scale)

Example Attribute Curves

Attribute curves determine value of a score of an attribute.

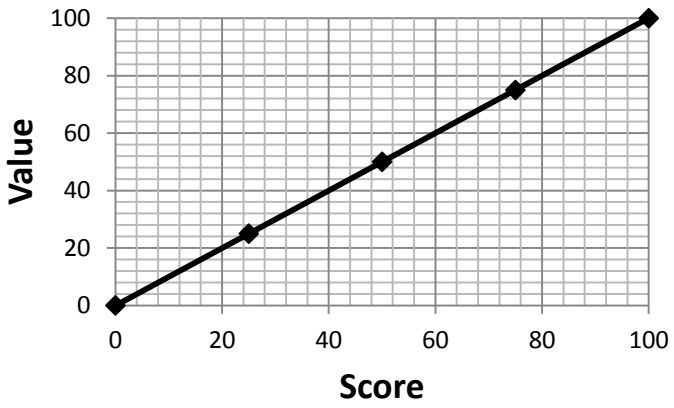




Survey Question

How did the future sensor capability impact your confidence in responding to a threat?

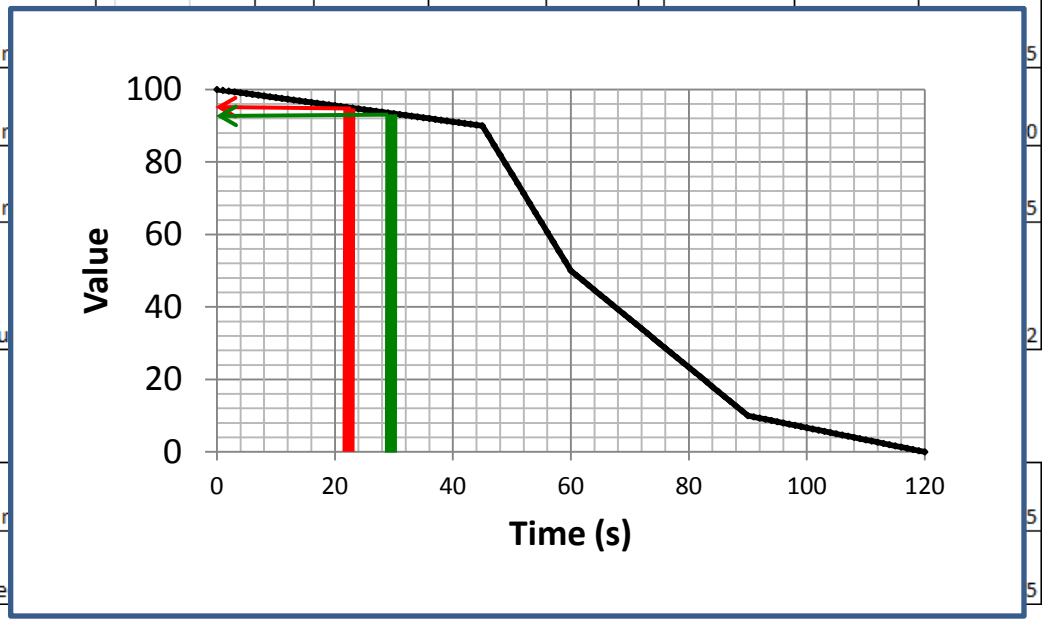
Greatly Diminished (0)	Diminished (25)	No Change (50)	Enabled (75)	Greatly Enabled (100)



Experiment Data Collection Example

Data from one participant in one run

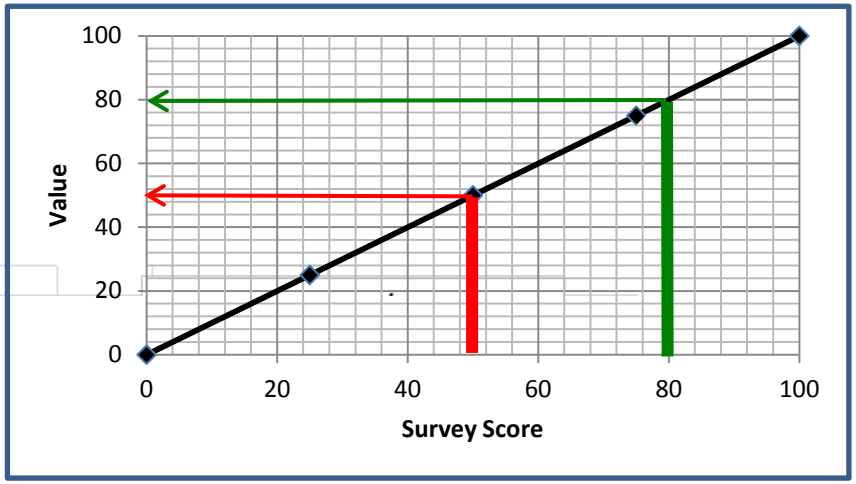
				EEA	MOM	MOP	Baseline			Enhanced		
Issue 1. (67%)	How does the future capability impact threat response?		METHOD	0.67			Raw Score	Value from model	Value input	Raw Score	Value from model	Value Input
	EEA 1.1 (67%)	How does the future capability impact situational awareness (SA)?			0.67							
		MOP 1.1.1 (10%)	What is the time from incident to detection?	timer		0.1	21	95.1	4.26904	30	93.3	4.188237
		MOP 1.1.2 (10%)	What is the time from detection to identification?	ti								5
		MOP 1.1.3 (10%)	What is the time from identification to decision?	ti								0
		MOP 1.1.4 (35%)	What is the time from incident to complete a SALT report?	ti								5
		MOP 1.1.5 (35%)	After a sensor failure, how was your ability to regain situational awareness impacted?	su								2
	EEA 1.2 (33%)	How does the future capability impact quantity and nature of communications?										
		MOP 1.2.1 (55%)	What is percent of phone/radio communication time?	ti								5
		MOP 1.2.2 (45%)	How many errors are there in the SALT report?	re								5



Experiment Data Collection Example

Data from one participant in one run

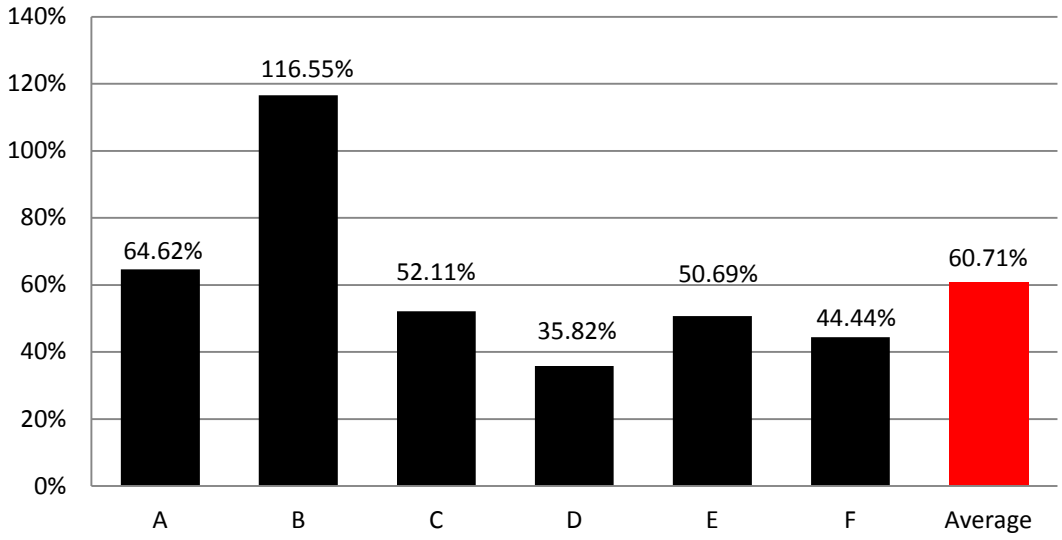
					Baseline			Enhanced		
					Raw Score	Value from model	Value input	Raw Score	Value from model	Value Input
Issue 2. (33%)	How does the future capability impact user control?			0.33						
EEA 2.1 (68%)	How does sensor data impact user performance?			0.68						
	MOP 2.1.2 (100%)	What is the workload impact?	survey	1	50	50	11.22	80	80	17.952
EEA 2.2 (32%)	What are the impacts on user confidence?			0.32						
	MOP 2.2.1 (100%)	How does the future capability impact user confidence in responding to a threat?	survey	1	50	50	5.28	90	90	9.504
							61.5263			85.9436945
								39.69%		
								Percent Overall Utility Increase		



25 min run					
12:41 mins on radio			7:57 mins on radio		
761.00	1500	50.73%	477	1500	31.80%
seconds			seconds		
			37.32%		
			Percent radio time reduction		

Results

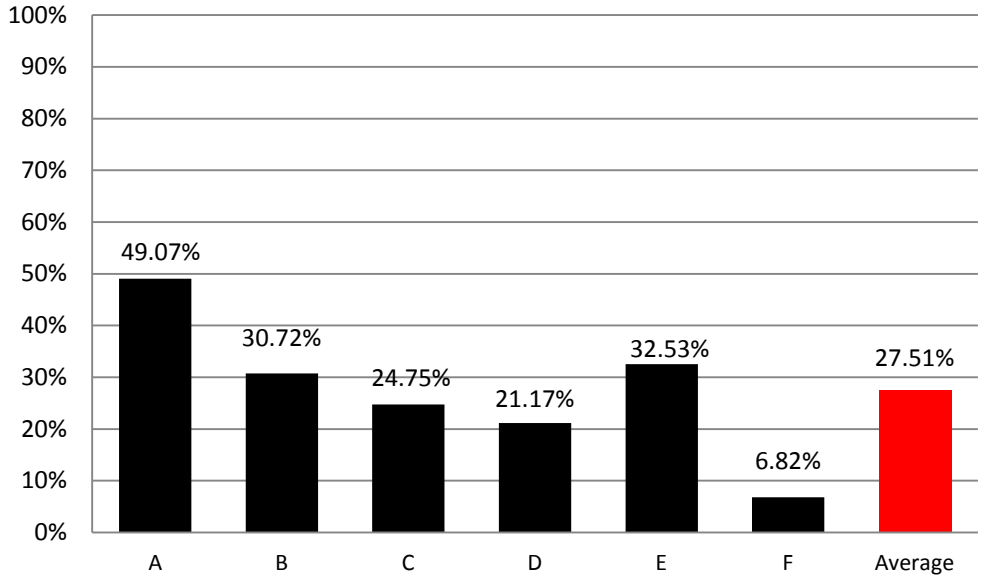
- 60.71% Overall utility Increase with the future sensor capability enabled.
  - Sensitivity Analysis showed that attributes are not sensitive to significant Issue and EEA weighting changes.



Participants' Overall Utility Increase

Results

- Each attribute can be individually analyzed.
  - Overall time spent on the radio decreased by 27.5%.



Participants' Overall Radio Time Decrease

Summary

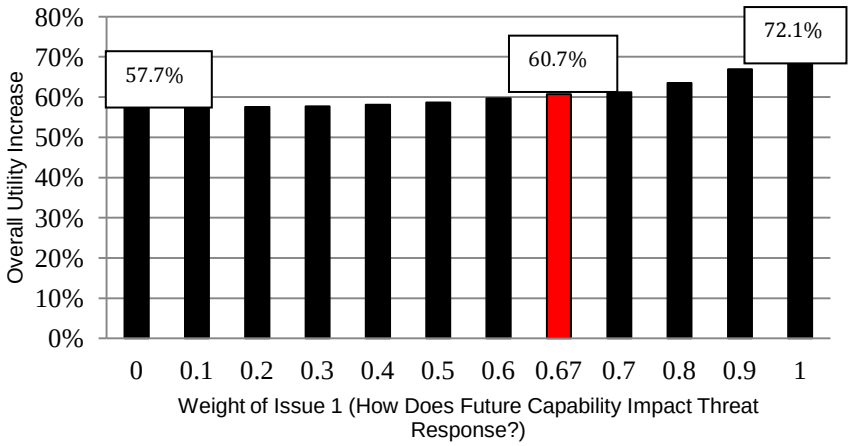
- Through the virtual BDOC, MSBL can accommodate contingency base and protection focused experiments and studies.

- MADM is a straightforward and effective method of determining “goodness” of a system or capability under evaluation.

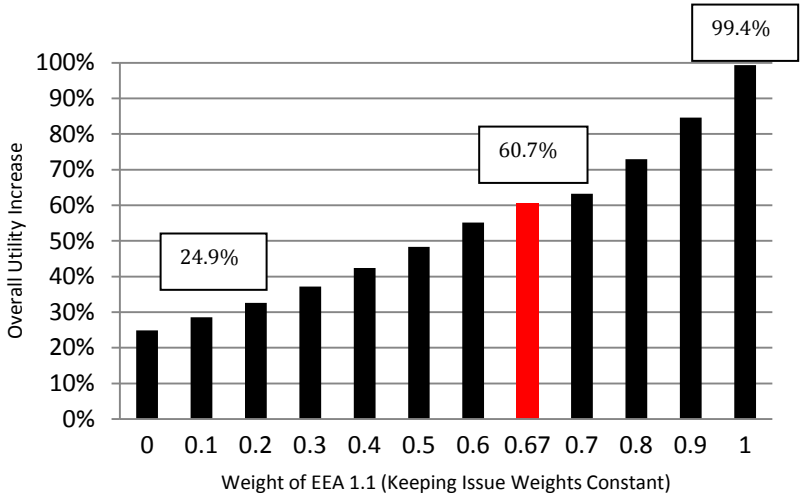
- MADM showed a 60.7% increase in utility of the future sensor capability, compared to a current baseline.

Backup

Sensitivity Analysis



Overall utility Increase Impact by Varying Issues 1 and 2 Weights



Issue and (weighting)	Essential Elements of Analysis (EEA) and weighting
Issue 1. (67%): How does future capability impact threat response?	EEA 1.1 (67%): How does future capability impact situational awareness (SA)?
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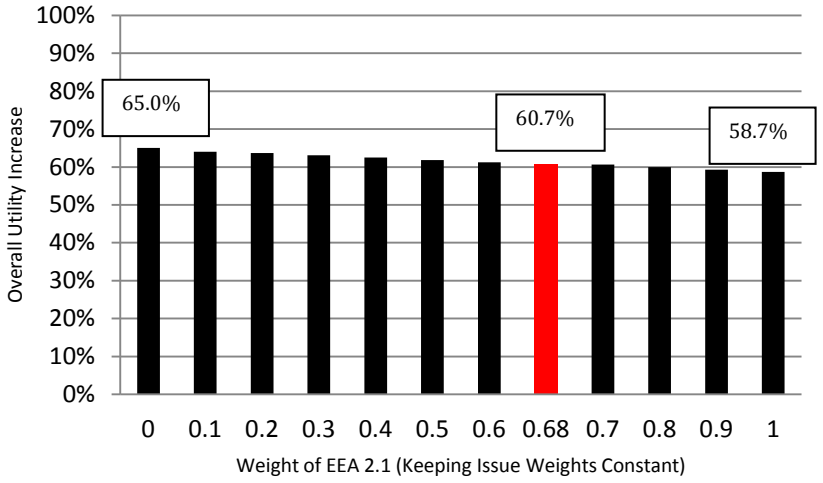
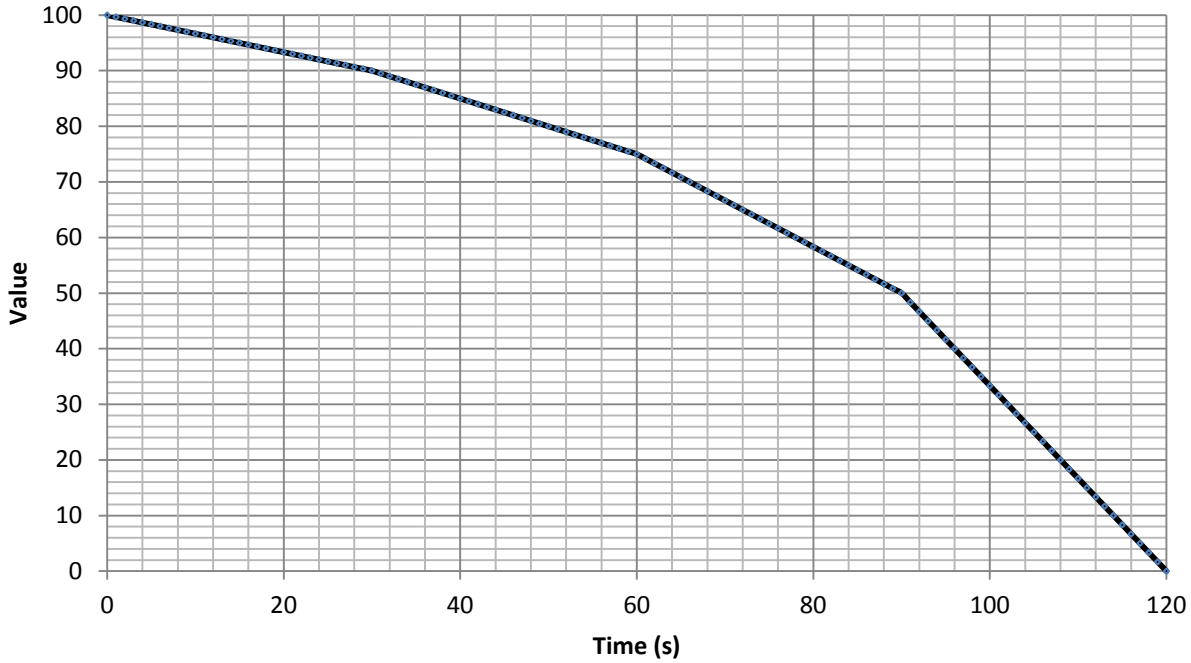
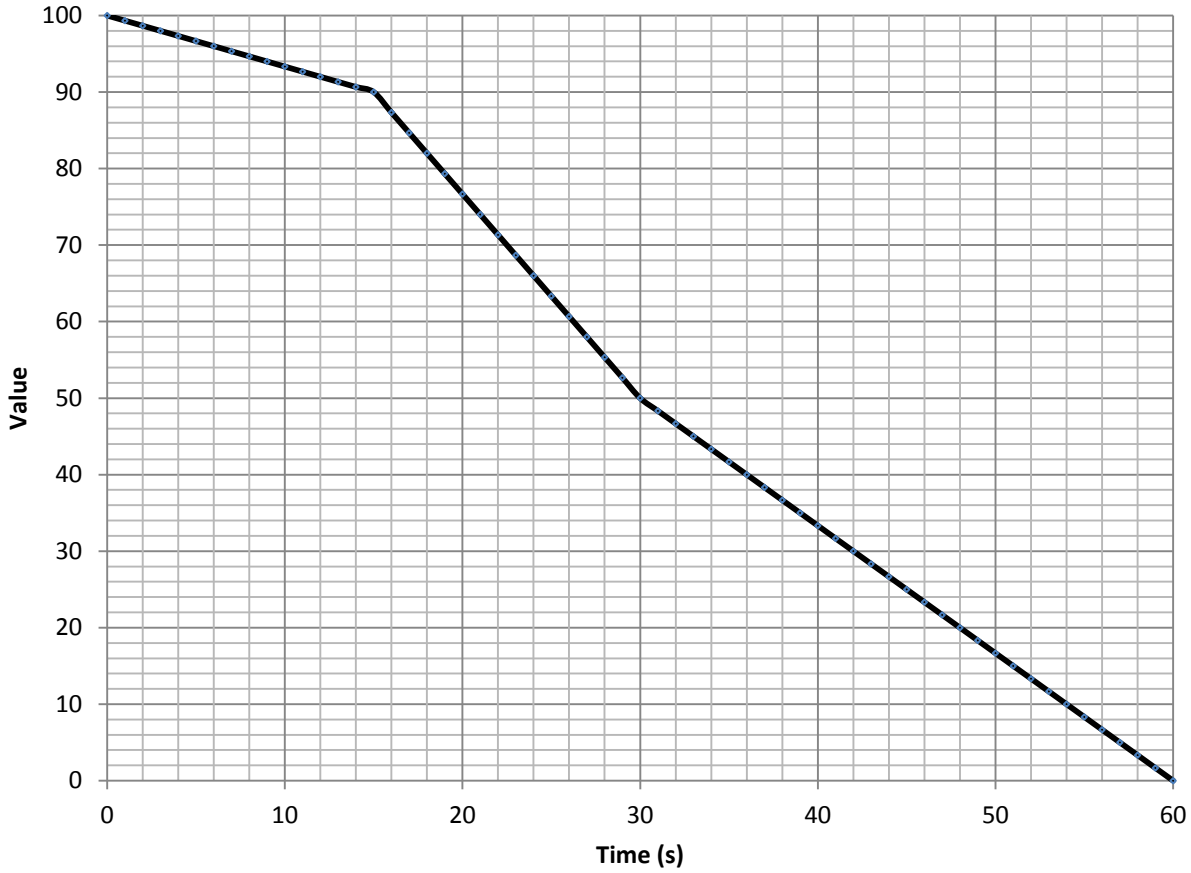


Backup – Utility Curve



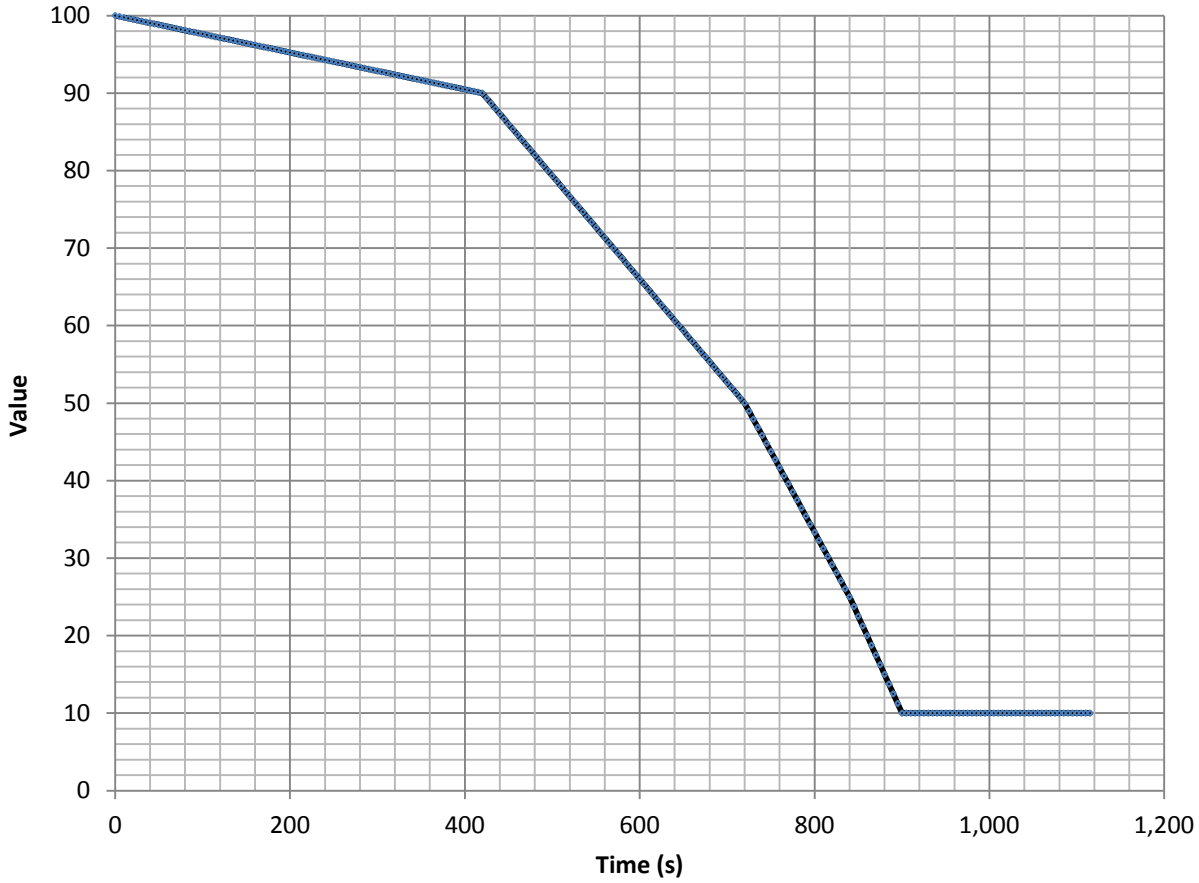
Time from detection to identification

Backup – Utility Curve



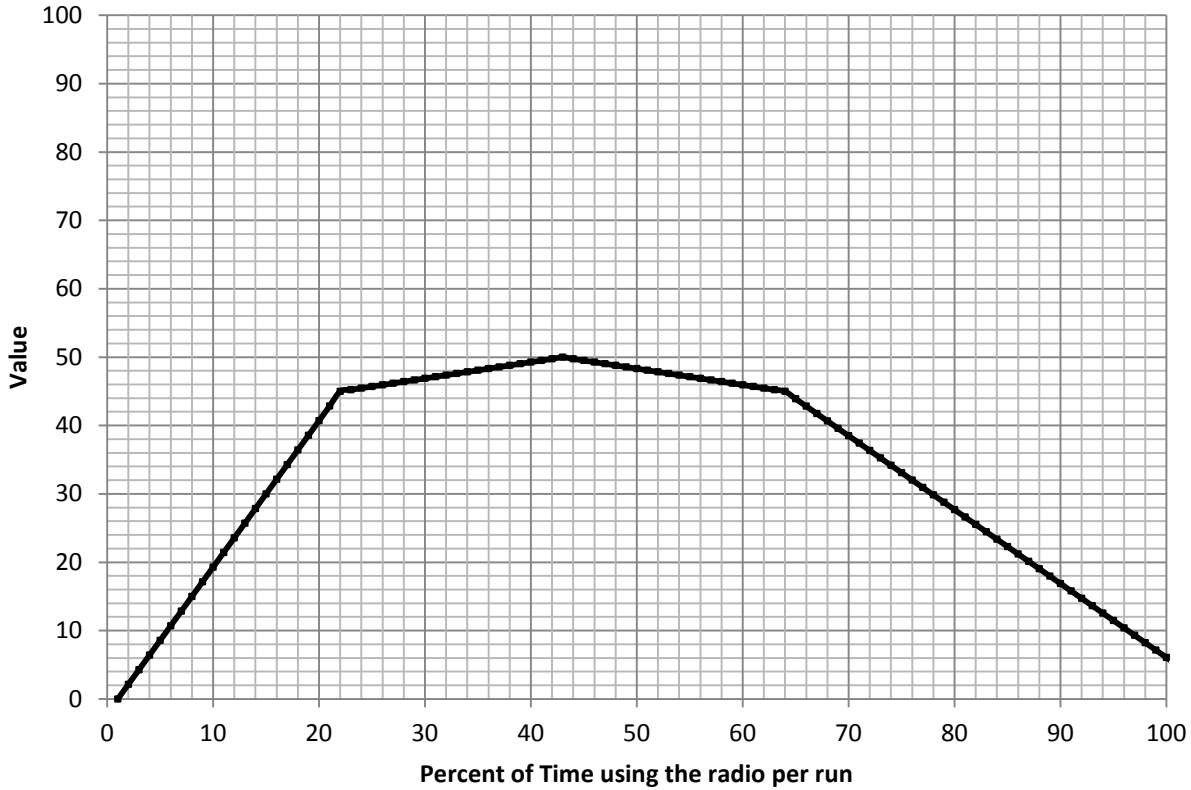
Time from identification to decision

Backup – Utility Curve



Time to complete a SALT report – from incident to completion?

Backup – Utility Curve



Percent of phone/radio communication time

Backup – Survey Questions

Survey Question 1: Suppose that your situational awareness is 100% at the beginning of a scenario. Indicate the value of how you regained situational awareness once the sensor failed.

Greatly Diminished (0)	Diminished (50)	No Change (100)	Enabled (150)	Greatly Enabled (200)

Survey Question 2: How did you feel that the enhanced system impacted your ability to take on more work load? Choose any number between 0 (greatly diminished) and 100 (greatly enabled). In this question, a value of 50 represents no change between the baseline and enhanced environments. Considering the first run (baseline) as a base line of 50, this question addresses the impact that the future capability had on the participant's ability to take on more work load, if it was required.

Greatly Diminished (0)	Diminished (25)	No Change (50)	Enabled (75)	Greatly Enabled (100)

Survey Question 3: How did an enhanced environment impact your confidence in responding to a threat? Choose any number between 0 (greatly diminished) and 100 (greatly enabled).

Greatly Diminished (0)	Diminished (25)	No Change (50)	Enabled (75)	Greatly Enabled (100)

Survey Question 4: How did your tactics, techniques, and procedures (TTPs) change in the BDOC with a baseline vs. ehanced environment?

Survey Question 5: What risks to base camps operations does non – baseline vs. enhanced uncover?

References

- RAID picture: http://peoiews.apg.army.mil/fb-n-11-15-11.html, accessed 12 Sep 14
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